Status Report

Theoretical Investigation of Radiation Damage and Transport Properties of Solar Cells

1 March 1965 - July 1966

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Research Grant No. NsG 649

Introduction

Theoretical investigation of the radiation damaged solar cells and general transport properties of semiconductors has been continued from two different points of view. One is to know the effects of damages caused by radiation on the electrical properties of semiconductors for various concentration ranges and for various species of damages. The other is to study how the radiation damages are annealed with elapse of time as the temperature of the sample is increased.

Current Research

1. A paper entitled "An Optimum Concentration Profile of the Drift Field Solar Cells and Transistors" written by P. H. Fang, T. Tanaka and J. A. Baicker has been submitted to the Journal of Applied Physics. An Optimum concentration profile of doping impurities in drift field solar cells and transistors, such that, the carriers moving under the drift field will reach the collection region in the shortest time, is found. This profile has the form of an exponential gradient of the concentration along the depth of the solar cell or transistors. This result is in agreement with that obtained from a very different approach. The method of solution of a class of non-linear differential equation might also be useful in the study of other kinematic problems.

2. "Method for Numerical Solution of System of Non-Linear Differential Equations" written by M. M. Sololoski and T. Tanaka has been submitted to the Journal of Applied Physics. A transformation is made on the initial system of non-linear differential equations so that the new dependent variables are small deviations from some initial value. For the transformed set of equations, terms of second order or higher, can be treated as a perturbation. An orthogonal transformation is, then,

introduced and the linear part of the differential equations is diagonalized. This set of diagonalized equations is solved by Green's functions method and by the method of iteration for a very small interval of the independent variable. The new set of values of the dependent variables thus obtained is now taken as a new set of initial values and the above procedure is repeated. A second method provides means for solving the equations when the orthogonal transformation introduced in the first method becomes indeterminate. The method is similar to that of complex convolutions. The kinetic equations for vacancy-interstitial annihilation with associated trapping of vacancies by one type of impurity for different activation energies are solved.

3. A paper entitled "Simple Power Law for the Introduction Rate of Deffects in Semiconductors under Steady Irradiation" written by M. M. Sokoloski and T. Tanaka has been submitted to the Journal of Applied Physics. The kinetic equations for vacancy-interstitial annihilation accompanied by vacancy-impurity trapping along with a constant vacancy-interstitial (Frenkel pair) source term have been numerically solved by computer using the methods in the previous paper. It is shown that the time regime can be superficially split into four regions, the second being elementary and the third being the steady state region approximated by a simple analytic expression. Some of the available experimental results on Si are compared with simple power law derived. Certain general conclusions about the model in Section 2, the introduction rate of Frenkel pairs, and other kinetic parameters are discussed.

4. Inverse Laplace Transform of a General Logarithmic Function has been calculated by T. Tanaka, P. H. Fang and M. M. Sokoloski. A need

for such a formula has arisen in the course of theoretical and experimental analysis of solar cells. Such a general formula as is found by us is not given in mathematical tables available. The result has a wide application and it has been submitted for publication.

Four papers listed above have been written in collaboration with NASA Goddard Space Flight Center, the staff (Dr. P.H. Fang and Mr. M. M. Sokoloski) and are supposed to have been reported as NASA internal progress reports.

5. A paper entitled "Green's Function Theory of Nonlinear Transport Coefficients" written by T. Tanaka, K. Moorjani and T. Morita which deals with a theoretical formulation of a general method of calculating non-linear transport coefficients will be sent for publication shortly. The formulation is quite general and it has a wide applicability. Mechanisms of ultrasonic amplification in semiconductors and microwave harmonic generation in magnetic insulators can be analysed from the point of view of the present formulation. Theoretical investigation of these nonlinear phenomena is under progress.

6. Mr. J. B. Jalikee (full time graduate assistant) has completed his Ph.D. thesis on the "Theory of Impurity Conduction in Semiconductors". In this formulation it is attempted to find the temperature dependence of the electric conductivity of impurity semiconductors over a wide range of impurity concentration. A general result is obtained which includes formulations of previous authors as special cases. The result will be sent for publication shortly.

Future Program.

1. Calculation of the Activation Energy of Vacancy Migration.

In the investigation of the annealing mechanism of radiation

damages in solar cells it has been assumed that the numerical value of the activation energy of vacancy migration is given. In order to find relations between annealing mechanisms and the transport properties of semiconductors it is necessary to calculate this energy from more fundamental properties of semiconductors.

2. Investigation of ultrasonic amplification in semiconductors will be continued from the point of view of the method of Green's function.

3. Impurity conduction in semiconductors. Further investigation of this subject will be carried out in order to have better understanding of the transport properties of solar cells.

Personnel

Tomoyasu Tanaka	Principal investigator. Full time during summer months. Visit NASA Goddard Space Flight Center regularly and participate in seminars and discussions.
Kishin Moorjani	Post Doctoral Fellow. Full time Sept. 1965 - present. Working on the optical properties and non-linear effects in semiconductors.
J. B. Jalikee	Full time graduate student working on the theory of impurity conduction. Finished Ph.D. thesis June, 1966. Post Doctoral Fellow. Full time July - 1966- present.
S. H. Brown	Full time graduate student until June, 1966.
E. L. Madsen	Full time graduate student July, 1966 - present